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ABSTRACT

A feasibility study was made of the implementation of key technology concepts, as espoused by the Engineering Council in collaboration with the Future Education Unit, into school, further education, and higher education curricula. Research--including national conferences, staff development seminars, and cross-curricular assignment work led to the conclusion that it is possible to introduce key technology concepts into curricula, but only with good planning, good management, and good will. A number of parallel steps toward a common target are suggested. The three principal areas requiring work are syllabus design, student-centered learning material, and staff development. It must be stressed that the key technology concepts cannot be tacked on to a traditional subject. Rather, it is a radical new approach that should engender changes of attitude in employers, providers, and students. However, the approach should improve the competitiveness of British industry well into the 21st century. (Recommendations for implementation of key technology concepts are made, and guidelines are provided for curriculum and planning. Examples of key technology education in specific courses are shown.) (KC)

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ED310236

THE CONCEPT OF KEY TECHNOLOGIES

An appraisal of current use

and thoughts for future implementation

in education and training

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CE053000

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RP485

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- Prue Taylour, Acting Director of Staff Development at GlosCAT, for conducting the staff-development day and national conference, and providing the basis of Chapter VI, 'Staff development implications'.
- Albert Clyde, Development Officer at the Further Education Unit, for his invaluable support and assistance throughout the project.
- The members of the steering committee, for their enthusiasm, support and many positive suggestions.
- The Further Education Unit for funding this project.

This report describes the background to the Engineering Council's key technologies[1], how their implications for education and training were explored by the Engineering Council and FEU[2] and analyses their place in current and future education and training schemes. The project (RP485) was undertaken for FEU by a team of lecturers at Gloucestershire College of Arts and Technology (GlosCAT).

The aim of the report is to assist educationists and trainers in supplying individuals with good technical, commercial and interpersonal skills so they are up to date with changes in technology and will meet the needs of a variety of industrial and commercial employers. **It is important to note that the report is about a new approach to the development of technological skills, rather than the technology itself.** Perhaps the most important point is that the adoption of the key technology concepts necessarily leads to **changes of attitude** towards industrial processes and the education and training to be able to work with them.

At this stage it is intriguing to consider why advances in technology happen. What circumstances existed that allowed television to be invented by Baird and radio signals to be transmitted across oceans by Marconi? In one sense these events may appear different. However, they have one set of circumstances in common. The technology to allow these advances existed, and was recognised and adapted by Baird and Marconi. They were able to perceive relationships between the technologies and create a situation conducive to their work. Again, in wartime — radar — or where national prestige is involved — the space race — a significant rate of technological development has been achieved — although in these cases at great financial cost.

Our aim, we suggest, should be to recreate these rates of development by the training of individuals in the key technology concepts. They will be able to recognise the importance of the combination of circumstances that will lead to advances in technology. The implication is that we should encourage learners to analyse and seek out such situations, often involving techniques, materials and processes that are not normally associated with each other. These engineers and technicians will have an educational background wide enough to encompass areas outside their immediate specialisation, and have the ability to work as members of an integrated team.

The GlosCAT team found that these concepts are rarely included directly in current education and training schemes, but could be incorporated, in particular within project and assignment work. They have, therefore, recommended a model assignment structure, and provided exemplars. One chapter takes the concept into the field of school technology, and describes how schools can co-operate in the overall aim of providing more, and better, scientists and technologists by incorporating the key technology concepts into their curriculum.

Noel Meeke has written a penetrating, and at times critical, report: his comments cannot lightly be disregard by anyone who

is interested in the welfare of technology in the British education system, and indeed of the national economy. The opinions offered are largely those of Noel and his team, but FEU found them sufficiently thought-provoking and indicative of ways forward to publish them with little editing.

FEU wishes to express thanks to Noel Meeke and the GlosCAT team for their detailed work and the clear and challenging presentation of the report. Noel and the team have since acted as consultants to a number of colleges which attempted to implement the GlosCAT ideas on project/assignment work; the aim is to publish a series of pre-tested projects and assignments for adaptation, and so provide a model for developments in other colleges. FEU intends that the results of this further work will be disseminated with the assistance of the participating colleges. Comments on this document should be forwarded to the FEU.

Albert Clyde
Development Officer
Further Education Unit

Our remit was a feasibility study of the implementation of the key technologies concepts, as espoused by the Engineering Council in collaboration with the Further Education Unit, into school, FE and HE curricula. We are satisfied, from our researches, national conference, staff-development seminars, and the cross-curricular assignment work we have developed, that it is possible to introduce key technology concepts into curricula, but only with good planning, good management and goodwill. We believe that it would be preferable to take small steps and consolidate good practice. However, this suggests a slow serial approach for which there is probably insufficient time. We therefore suggest a number of parallel steps towards a common target:

> the implementation of key technology concepts within a timeframe as short as resources and good practice will allow.

The three principal areas requiring further work are:

- syllabus design;
- student-centred learning material;
- staff development (teaching and support staff).

Further development work of a true cross-curricular nature needs to be done to examine issues. It should be recognised that the key technologies concepts cannot be bolted on to a traditional single subject — that is the vital point of this report. During the early stages, staff development should be carried out by those closely connected with the evolution of the key technology concepts, perhaps at regional centres. The cascade approach should be used for wider dissemination, but only under close control and in pre-planned programmes which can be monitored.

Resources will naturally be required to carry through these recommendations. We suggest that funding be sought from bodies whose natural function this is, e.g. FEU, the Training Agency, local education authorities through their Training Grants Scheme (LEATGS) or research and development provision, and those who will benefit from the improved student output, namely commerce and industry. This does not mean, however, that all educational bodies and institutions should wait until prodded into action. Aspects of key technology concepts are already being addressed in many establishments via, for example, team teaching and assignment programmes. These organisations should note the findings of this report and use them in any way possible to increase their impetus.

At a late stage in our research, a member of the steering group suggested that we extend the key technologies concept to non-scientific or non-technological curricula. Undoubtedly there is much room for further work to be done in this direction, but it was not feasible within our funding and timescale. We would, however, urge that these aspects be explored and funding allocated to a suitable research group to carry the work into non-technical spheres.

The concept of key technologies is not an addition to existing schemes. It is a radical new approach which should engender

changes of attitude in employers, providers and students alike. As the joint paper[2] indicates:

> The key technologies are the supporting structure for designing new products and processes and so form an element of competitiveness. They should be considered in relation to the activities of research, design, development, production, finance, quality, marketing, sales and service.

The fulfilment of the concept can be achieved only if it permeates the entire education and training system, changing attitudes which have formed over long periods, thereby producing an improvement in the quality of technicians, engineers and others required by British industry and commerce. It should be seen as a continuing strategy, flexible enough to accommodate changes in future technology currently incomprehensible, which will improve the competitiveness of British industry well into the twenty-first century.

To FE/HE management and staff:

- Aim to change the attitudes of students towards science and technology by introducing the concepts of key technologies into all syllabuses. This can only be achieved by altering your own attitudes first.
- Regularly review, and where necessary rewrite, all science and technology syllabuses to introduce the concepts of key technologies. The matrix developed for this report may be found helpful.
- Consider how the 'broadened horizons' implications of the Higginson Report on 'A' levels may be implemented in the further, higher, adult and continuing education sectors.

To the Secretary of State for Education and Science:

- Consider broadening the 16-18 curriculum by taking into account the concepts of key technologies espoused in this report.

To BTEC:

- Develop the general 'industrial studies' unit at higher and national level.
- Make 'the concept of key technologies' a theme in all units.
- Strengthen links between guidelines and units.
- Make higher units less narrowly specialised.

To C&G:

- Develop and introduce into syllabuses the concepts of key technologies.
- Strengthen links between guidelines and syllabuses.
- Create syllabuses which are less narrowly specialised and dedicated to contemporary requirements.

To NCVQ:

- In determining your criteria, take account of attitudinal issues necessary to cope with technological changes beyond the immediate future.
- Require syllabuses to encompass elements of the key technologies and expand beyond the immediate competence requirements of contemporary employment.

To employers:

- Consider your requirements in the longer term and encourage all phases and branches of education and training to heed the concepts of key technologies, and so produce young employees with skills and attitudes flexible enough to take new technologies in their stride.

To FE/HE and training management:

- Plan to incorporate the concepts of key technologies, as appropriate, into:

  — teaching and learning strategies;
  — staff development (teaching and support staff);
  — course management and development;
  — staff review;
  — team teaching;
  — timetabling;
  — resource allocation;
  — co-operation with other institutions and industry.

  (Schools are recommended to explore similar ideas at an appropriate level.)

To the TVEI sector:

- While this report has primarily been directed towards FE/HE, we believe that its research and findings may be of equal value and significance to the development of the extension of TVEI.

To LEA financial management:

- In preparing schemes of financial delegation to colleges, it is important that the curriculum issues discussed in this report should be taken into account in determining college budgets under schemes of delegation.

PART ONE

The term key technologies was first used in a paper issued by the Engineering Council, *A Call To Action: Continuing Education and Training for Engineers and Technicians*[1] . It was suggested as a replacement for the earlier concept of enabling technologies in order to provide a term embracing the three aspects of engineering activity: materials, components and systems.

In their paper, the Engineering Council defined key technologies as:

> newly emerging topics in science and engineering which are likely to have a major evolutionary effect on an existing product or process or may lead to a revolutionary new product or process.

Some of the implications of the key technologies concept for education and training were addressed subsequently in a joint occasional paper by FEU and the Engineering Council, *The Key Technologies*[2] . The foreword identifies a key issue in the paper:

> Considerable progress has been made in improving efficiency of British Industry but there is still a long way to go... the concept of 'key technologies' has important implications for all providers of education and training... Industrial and commercial employers need individuals with good technical, commercial and interpersonal skills who are able to keep up to date with changes in working practices and technology.

What the engineer, technician and provider of education and training should recognise is that adoption of the key technologies concepts necessarily leads to changes of attitude towards industrial processes and the supporting education and training. To this end, key technologies will encourage engineers and technicians to develop an educational background wide enough to encompass areas outside their immediate specialisation. Similarly, if adopted, key technologies will provide sound guidelines for the future planning of education and training. Each branch of industry will have its own identifiable key technologies, which by definition have the potential to improve competitiveness. The compilation of lists of such technologies is unproductive because any such catalogue will be rapidly out-dated, and probably distracting. (However, examples are given in Reference 2.)

Although changes are under way, current education and training in technology is mainly highly subject specific, stemming largely from rigid division of science into areas such as chemistry, biology and physics. Industries' needs are almost always interdisciplinary; this is one reason why education is outpaced by the changes constantly taking place in industrial society. While continuing education and training can help alleviate knowledge and skill deficiencies in specific areas, the longer term solution must lie in fundamental changes in educational attitudes and processes. From the joint paper[2] :

> In preparing students for an uncertain future, educational institutions need to enable them to learn fundamental principles, including *design*, which underpin the development

of specialist expertise as well as *economic awareness* and associated *management* and *business skills*.

(Our emphasis)

While it may be possible to forsee some of the short-term developments in science and technology, longer-term activities are much less certain. When the vast range of scientific advances are plotted against time, one can begin to appreciate the exponential growth in innovation. There is also a general shortening of the periods taken to bring new scientific discoveries into practical use (Figure 1). We have become so used to this that the general expectation is that a cure for viral infections, e.g. acquired immune deficiency syndrome (AIDS), is simply a matter of time. Similarly, we tend not to be very concerned at the consumption of fossil fuels, on the assumption that energy from nuclear fusion is a foregone conclusion within the timescale. Figure 1 compares the period of 112 years to develop photography against 56 years to introduce the telephone and only six years for the atomic bomb. We believe that we should prepare our young people for an exciting but rapidly changing world tomorrow. Future technologies must be reflected in today's approach to education and training.

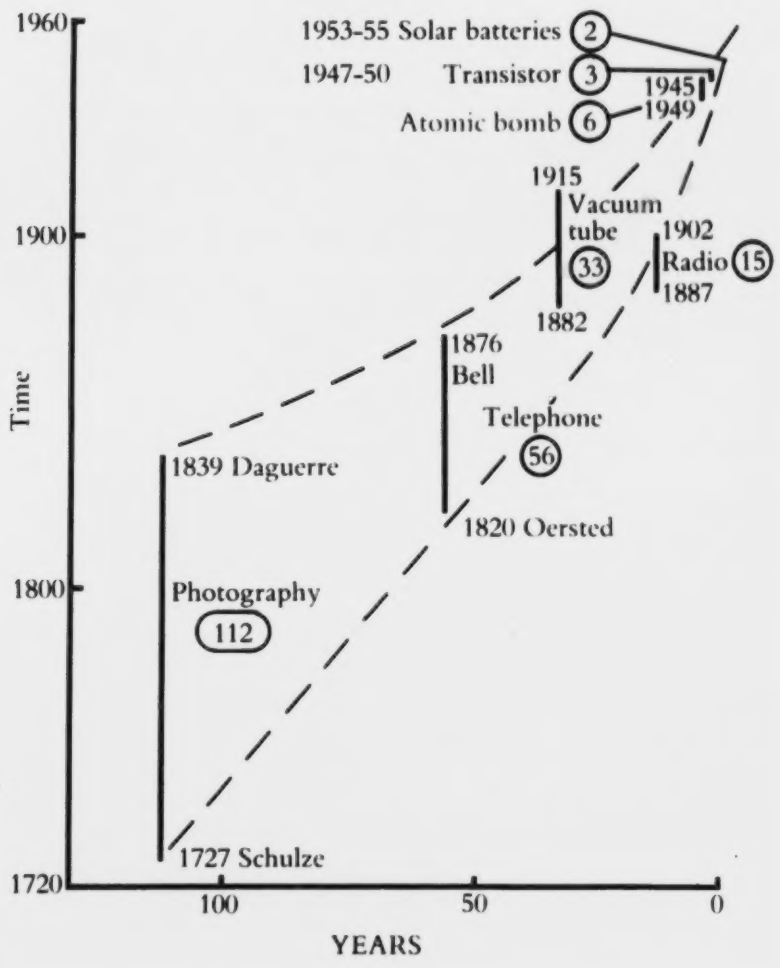

Figure 1 — The period between scientific discovery and innovation

The United Kingdom must learn to operate in a rapidly changing world economy — a world of increasingly competititive markets, rapid technology transfer, and even shorter product life cycles. Certainly, one key to this is technology. Historically, technological discoveries and developments have been a key factor in increasing competitiveness and raising the standard of living. Technology is probably the largest contributing factor to productivity improvements, economic growth and increased employment. Too often in the past we have focused on economic factors, overlooking the failure to develop and implement new technology. A more balanced view is necessary, especially one which gives greater weight to science and technology in education if we are to achieve long-term goals.

At both school and college levels, education must impart to the potential workforce the knowledge and skills not only to perform current jobs but to meet the future needs of industry. To a large extent, the nation's ability to compete in the global marketplace depends on a workforce that can not only understand and apply its training in mathematics, science and technology advantageously, but has been given the opportunity to study cross-curricular themes including economics, business studies and marketing. In this respect our technical education system needs considerable improvement.

We have seen great advances in information technology and the ways in which it has revolutionised not only business and industry but our everyday lives. We now have microprocessors in washing machines, cameras, cars and industrial robots. To an extent we have allowed these events to obscure the many simultaneous advances in industry which are not directly related to information technology.

Engineering is concerned with the creation of products of value. To create wealth we must put added value into products. Technology is one key means of achieving this and can help a company increase its competitiveness by:

- producing products which anticipate market need;
- gaining market share from competitors by product differentiation;
- replacing mature technology to maintain advantage;
- exploiting new technology in methods of production.

The classification of technology clarifies our thought processes and helps prepare a technical strategy. As we shall see in later sections, we believe in the need to work (and learn) from the whole to the part. In developing strategy, this helps avoid making random attempts at improvement which may address the wrong issues. Sometimes there is confusion between technology levels and types of technology; this is where classification helps.

LEVELS OF TECHNOLOGY

- Materials
- Components
- Manufacturing and process

We believe that most technologies can be classified into one of these levels, although there may be considerable overlap.

OTHER POSSIBLE CLASSIFICATIONS

Classification	*Examples*
By subject area	Energy, IT, communication, materials, biotechnology
By end user	Industrial, commercial, domestic, leisure
By time	Yesterday, today, tomorrow, obsolete
By importance to user	Income generation, public good, environment protection
By strategic significance	Sole ownership, patentable, accessible, remote
By importance to business	Obsolete, key, developing, mature

The last classification contains the word key in its examples. These key technologies may occur within any of the levels of technology, or indeed within any of the other classifications.

Key technologies:

- are often (perhaps usually) interdisciplinary;
- are innovative;
- have a wide range of applications;
- have evolutionary effects on products and processes;
  or
- lead to new products and processes.

Figure 2 shows the innovation process. Non-technical aspects of technologies play an important role in the definition of key technologies.

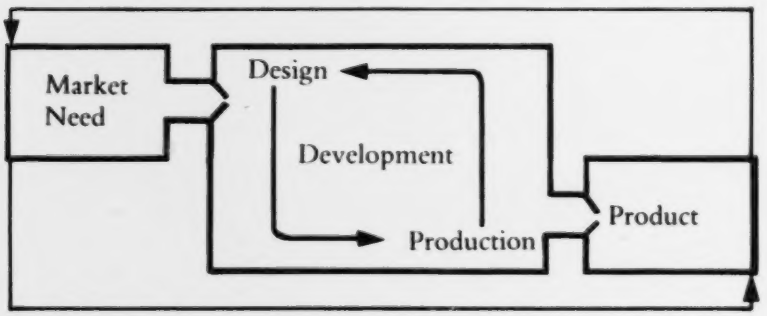

Figure 2

At national level we should examine those technologies which enhance international trade. We make take as an example a microcomputer. This comprises a case, a microprocessor, memory and other electronic devices, a keyboard, input/output connections and a visual display unit; in other words a collection of what we now regard as mature components. Many of the innovative stages took place in the UK, but as a nation we should guard against becoming dependant on assembling technologies that have been developed in other countries. This applies as much to the automotive industry, for example, as to computers. The high added value stemming from the design and production of standard computer components lies not with British industry. This is regrettable and means that the techniques which create this wealth lie outside our control. The design, development and mass production of silicon microchips, the heart of the computer, depend upon the skills of engineers who are versed not only in atomic structure, semiconductor processes, heat transfer and production techniques, but also in economics and market forces. Other countries have become aware of this, especially those on the Pacific rim. Britain, alas, has not.

We referred earlier to the automotive industry. No longer is a motor car a collection of standard mechanical and simple electrical components. It is a highly innovative and multidisciplinary product whose sophistication, even in family cars, increases every year. Where there used to be a carburettor and distributor there is now an engine management system controlled by a microprocessor. In the forseeable future we shall have automatically controlled tyre pressures, anti-collision radar or sonar, and automatic road toll payment triggered by signals individual to our car. If that is foreseeable, what is over the horizon? It is because of this unforeseen technological demand which will occur within the working life of today's young people that we must prepare them, not simply technically but by fostering the new attitudes they will need.

To a large extent the British attitude towards technological development is blinkered. Engineering institutions, trade associations and other professional bodies are, in the main, single-discipline. Education, stemming from the clear eighteenth and nineteenth century divisions of science into chemistry, physics and biology, has encouraged technology and research to grow within fixed subject areas. This is still true, for example, in 'A' level syllabuses and many university courses. It may have served us well in the past but it is now, we believe, a hindrance to progress. Industry finds increasingly that new developments are not confined to one discipline. It needs to take in individuals who not only have experience and knowledge in more than one technological discipline but also have the flexible attitude of mind to work in a team, set in an inter-disciplinary environment.

Changes of attitude are essential. We are not simply talking about chemical engineers working with civil engineers. We must integrate technical disciplines with each other and with the disciplines of business and commerce, language and communication. We need people with the fertile imaginations and lateral thought processes to turn today's science fiction into tomorrow's science fact. We cannot separate science and

engineering from the rest of life; this change in attitude must spill over into technology and encompass economic awareness. We see these twin threads running through the curriculum from primary school to adult life. Figure 3 indicates the need for a continuum in education and training which should be fully developed if we are to set technology into the widest possible framework and prepare our young people for the real world.

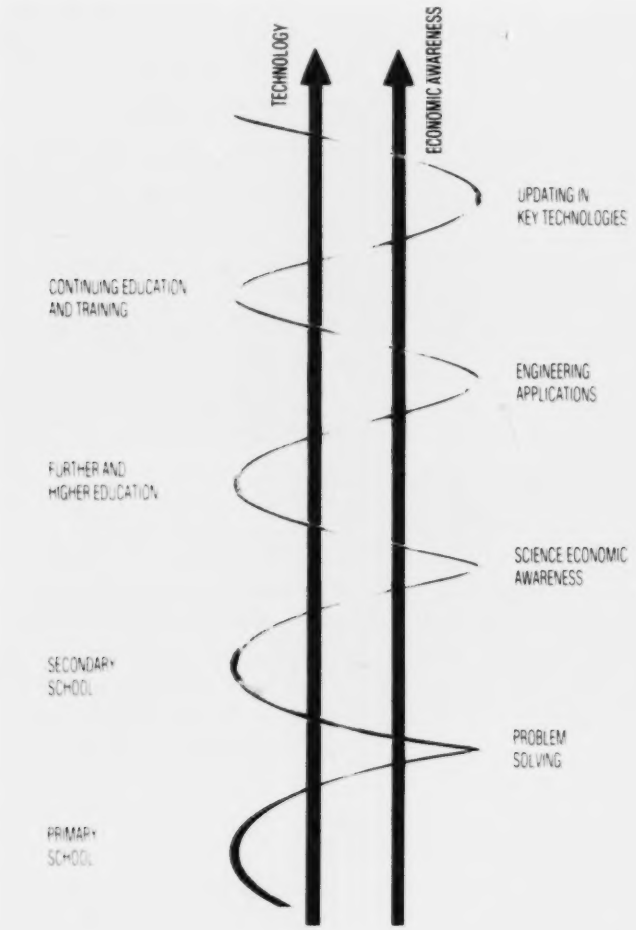

Figure 3 — The spiral curriculum and the key technologies

The FEU/Engineering Council joint paper[2] suggested that there should be a regular review of technology-based curricula to ensure that course content and methods of learning are up to date:

> Each educational establishment should identify which of the changing technologies it should use as examples in its teaching. The emphasis should be placed on practical examples and the development of economic awareness at all levels in the curriculum.

Colleges, when reviewing their programme of courses annually, should think in terms of a rolling development plan. The paper recommends that these regular reviews give consideration to:

- changes in technology affecting existing programmes;
- possible need for new programmes;
- staff training implications.

As a consequence of these recommendations, FEU invited a cross-disciplinary team at Gloucestershire College of Arts and Technology:

- to review FE/HE curricula to
  - — identify current applications of science and technology that are consistent with the concept of key technologies,
  - — identify further opportunities for inclusion of the concept of key technologies,
  - — design sample projects illustrating the application of the concept of key technologies;
- to make recommendations and prepare relevant materials for staff-development issues arising from the introduction of the key technologies into the curriculum;
- in conjunction with other relevant bodies to make recommendations regarding the implications of the key technologies for school-based education.

The inter-disciplinary team convened for the purposes of this report comprised school, further education (FE) and higher education (HE) staff, all of whom had a deep interest in furthering cross-curricular integration. The author was a founder member of the Gloucestershire Local Education Authority (LEA) Advisory Panel for Technology, which allows the natural fusion of development work in the county's schools with that in FE/HE. The chair of this county advisory panel was the schools' representative in the team. The FE/HE technical and philosophical input has stemmed from four lecturers in the disciplines of biotechnology, electronics and telecommunications, mechanical and production engineering, and the physical sciences. The Acting Director of Staff Development for the college has been working closely with the team throughout and has directed the internal seminar and national conference associated with the project, as well as contributing input on the staff-development aspects of the key technologies concepts. The

author, with a background in electronic engineering and medical physics together with business skills and marketing, had wide experience of industry before entering FE/HE.

The methodology adopted includes examination of a range of FE/HE science and technology schemes, seeking to identify current examples of the applications of the key technology concepts, and possible opportunities for their further inclusion in the schemes. The process was assisted by the analysis of schemes against a framework developed by the team and based on a matrix incorporating the main key technologies concepts. For school-based education, a sub-group adopted a modified approach more suited to the learning methods of the 5- to 16-year age groups. Exemplars of FE/HE project work have been developed which illustrate the wide-ranging nature of the key technologies concepts.

A steering committee representative of a cross-section of school, further and higher education, and industry was established and provided invaluable assistance and liaison with a much wider educational and industrial scene. Of particular importance were the links with industry needs and training methods, examining and validating bodies, and staff-training requirements, as the key technologies concepts are fitted into the framework of education and training.

The project research team developed and used a matrix for analysing current syllabuses, which lends itself to:

- assessing the presence of the key technology concepts;
- indicating possibilities for their further inclusion.

Column headings are broadly divided into key technology and curriculum aspects, as the latter will have a profound influence on the achievement of the former. The four key technology sub-headings reflect in short-hand form the main characteristics of key technologies as described in the FEU/Engineering Council joint paper[2], viz. they will:

- be interdisciplinary/innovative topics in science and engineering ('technology status');
- have an economic impact, not simply related to profit but on society as a whole ('economic effects');
- have a major evolutionary effect on an existing product or process, or may lead to new products or processes ('evolutionary effects');
- have a wide range of applications in products and processes, resulting in high added value ('application areas').

The curriculum aspects are also sub-divided into four, which reflect the elements necessary for the delivery of the key technologies concepts.

The matrix has been used to analyse the following syllabuses (Appendix 1 shows a sample):

- BTEC Level F Instrumentation and Process Measurements;
- BTEC Level F Science;
- BTEC Level N Manufacturing Technology;
- BTEC Level N Microelectronic Systems;
- BTEC Level H Microcomputer Systems;
- BTEC Level H Physics;
- University of London 'A' level Physics;
- C&G 236 (Electrical Installation) — generalised analysis only as this scheme is under revision.

From the analyses, meetings with other bodies, and work of the schools sub-group, a distinct pattern has emerged which suggests that the key technologies concepts are currently appearing most strongly at school level, especially primary, and taper off progressively through FE to HE. This may reflect the fact that generally the higher the level, the more specialised subjects/modules become. Perhaps the most striking difference is between GCSE and 'A' level; our investigations appear to indicate that the former provides little preparation for the latter. The main thrust of the Higginson Report on the future of 'A' level examinations was broadly coincident with the key technologies concepts and offered opportunities for greater harmony and transference between GCSE and 'A' level.

Industry and commerce need people who can, in the words of the Higginson Report[3]:

> think and apply their ingenuity.

Examinations should favour this approach rather than testing:

> more shallow skills, like the ability to recite something parrot fashion. A rigorous examination calls for more than the acquisition of factual information and other people's arguments; it calls, for example, for the skills of analysis, the ability to see connections and differences, and the capacity to understand. Learning facts provides a start, but making sense of them is what matters.
>
> An essential part of the syllabuses should be that they promote *understanding* and those *skills* and *attitudes* which come with understanding — such as *initiative* and *confidence*, *creative thinking*, *adaptability* and the capacity *to work independently with others*.
>
> (Our emphasis)

The concept of 'AS' levels was to redress the balance, encourage broader horizons and give greater breadth to sixth form curricula. But without changing the shape and purpose of subjects which are traditionally of relevance to science and engineering and those which we believe should be integrated into the whole curriculum directed towards technology, such as economics and business studies, the 'AS' concept may not achieve its purpose. The fundamental problem is that 'AS' syllabuses are cast in the same moulds as 'A' levels: they demand the memorisation and regurgitation of facts. The key technology concepts demonstrate that today's facts can be tomorrow's bygones, and require people who are able to find and access facts when technology has changed, and relate them to tomorrow's world.

Turning to our analysis of BTEC units, the key technologies concepts do not appear strongly within the units but tutors are recommended in the accompanying guidelines, and through the programmes of integrative assignments, to follow pointers which reflect some of the key technology concepts. From discussions with BTEC, it is noted that courses are intended to establish basic principles and concepts which are enduring and help the student react to change through the possession of transferable skills. However, courses may contain units, particularly at higher level, which are more specialised and deal with ephemeral technology. To offset this effect, a general unit of industrial studies is being designed, which will include elements concerned with economic awareness, business studies, and the impact of industry on society as a whole, and is intended to run alongside specialised technological units. There is also a move towards key themes running through related groups of higher units and the key technologies concepts could become such a theme. It would then pervade all related units and provide greater integration of the units with the programme of practical activities such as integrative assignments and case studies. Strengthening the links between BTEC guidelines and their respective units would be advantageous, but BTEC is not intending to reshape the

guidelines at present. Teamwork at institutional level is deemed crucial by BTEC which believes that this approach will ensure that all team members have their attentions drawn to the guidelines. Only when the new patterns of team working, programmes of integrative assignments and other related changes have been thoroughly established and seen to have settled down will new concepts like key technologies be introduced.

The City and Guilds of London Institute (C&G) syllabus considered (Scheme 236: Electrical Installation) shows virtually no references to key technology concepts. (It is, however, currently under review into a competence format.) C&G expects that tutors will bring out the concepts through their classroom and practical-work strategies. C&G emphasise that its schemes are produced in conjunction with relevant craft bodies, training boards and industry, and are specifically related to competences required by those bodies, boards and industries. As it is part of an industrial classification scheme, the structure endeavours to omit all content which is not relevant to industrial practice for the purpose of certification. Nevertheless, the skills developed are not confined to any one industry or current practice. Furthermore, the electrical industry invites optional study of communication, science and information technology and is one in which advancement is available to those with initiative to improve their achievements in these areas. A current task of C&G is to create a computerised data bank of specific process-competencies, from which items may be drawn to create any skills-based programme required in the future. This particular activity forms part of an overall plan to dovetail C&G qualifications with the requirements of the National Council for Vocational Qualifications (NCVQ). As with BTEC, guidance for tutors is provided in separate publications. An example is *The Background to Technology: The Teachers' Book*[4]. In its opening paragraphs are statements concerning the changes in society wrought by industrial, technological and market forces which reflect many of the key technology concepts. Unfortunately, the number of staff aware of such guideline material, who teach C&G syllabuses, is open to question, even though some of it is available at no cost.

The White Paper *Education and Training for Young People*[5] suggested, *inter alia*, a review of vocational qualifications. This led to a working party which called for a National Council for Vocational Qualifications (NCVQ), which was set up in October 1986. It was required to establish a coherent national framework for vocational qualifications and to ensure that qualifications relate to competent performance standards in employment. This has had an important influence on the FE system and the impact of the changes on vocational qualifications is now being felt. The NCVQ framework is summarised in a recent FEU paper, *NCVQ and its Implications*[6]:

> The aim of the framework is to bring all relevant vocational qualifications into a national system in order to make them more comprehensible, and to aid progression by clearly showing the routes available to those seeking qualifications.
>
> The framework consists of four levels to which vocational qualifications will be allocated. These levels are of

occupational competence as defined by the industry concerned. Consultations have led to the government's agreement to extend the NVQ framework beyond level IV, although the number and definitions of the new levels have yet to be agreed.

The target date for completing the job of placing vocational qualifications for the main occupational sectors at levels I to IV into the framework is 1991.

In the preface to the NCVQ publication *The NVQ Criteria and Related Guidance*[7], the Chair of the National Council made these points, among others:

Employers must have confidence that qualifications are directly relevant to employment needs. To this end, National Vocational Qualifications will be based on a clear specification of the competences and standards which industry and commerce say they require.

People need to have greater confidence that the training and education routes on which they set out will allow them the opportunity to fulfil their individual potential.

NCVQ will not itself offer qualifications. It is not an awarding body. Its function is to put the seal of approval on those qualifications, designed and submitted to it by awarding bodies, which meet the NCVQ criteria.

The criteria laid down by NCVQ, by which qualifications will be considered when submitted for accreditation by the National Council, are intended to be a model. The purposes of the model are to provide for the design of new qualifications and the adaptation of those currently available. In abbreviated form, the criteria the NCVQ adopt when considering awards for accreditation include:

- competence relevant to employment;
- competence has been determined/established by responsible bodies related to relevant sectors of employment;
- competence must be an outcome of learning, and must be demonstrated and assessed;
- award must be free of any barriers which might restrict access;
- competence in a significant range of work activities;
- level of attainment reflects a national standard;
- competences should take account of foreseeable changes in technology, market requirements and job structures *for the period of accreditation*;
- a basis for progression to higher levels, *but not necessarily a knowledge or understanding beyond the needs of the employment to which the award relates.*
  (Our emphasis)

We observed earlier that, in tailoring their awards to the NCVQ criteria, C&G are specifically relating all competences to those required by the bodies they liaise with, representative of commerce and industry. We believe that this approach exposes the dangers to the future of technological industry in this country. The competences which are being learned and assessed will undoubtedly be of immediate benefit to employers, but at a

time of drastically reducing numbers of youngsters of school (and college) leaving ages more attention should be directed towards general competence, and the ability to create a flexible workforce. Lest this be thought an over gloomy view of the attitudes of some employers, we can cite examples of young people leaving YTS and BTEC full-time courses for the short-term attraction of high wages. They fail to realise the long-term consequences of accepting such tempting offers. British industry has always found it difficult to take the long-term view, whether investing in plant and machinery or in its future skilled workforce. Therefore, basing award criteria so heavily upon the requirements of commerce and industry is open to question.

The NCVQ criteria include references to competences which should take account of changes in technology, the marketplace and job structures. It will be necessary to ensure that re-accreditation (after five years) takes the updated situation into account. The concept of key technologies is to provide students not only with knowledge, understanding and skills of immediate consequence, but with longer-term attitudes which will enable them to adapt to changes in technology, the marketplace and job structures during their working lifetime. Certainly, the path illuminated by key technology concepts and that enshrined in the NCVQ criteria appear to be potentially divergent. We believe that, for the future of British industry, this is a disturbing trend.

PART TWO

What emerges from Chapter III is that, by and large within the syllabuses examined, virtually no references are made to material which may be construed as reflecting the broad key technologies concepts. Nor is there much comfort to be found in the criteria laid down by NCVQ which is now having such a profound influence on post-16 training and education. The main thrust of the key technology concepts is the changing of attitudes and this may be difficult to achieve within the cold print of a syllabus. What can be provided, however, are regular pointers or signposts to the aspects of key technologies acknowledged in the headings of our analysis matrix:

- technology status;
- economic effects;
- evolutionary effects;
- application areas.

We advocate their inclusion as stimuli to teaching staff to make students aware of the broader effects of the topic under consideration, and reduce the blinkered vision of specialisation.

We have seen that both BTEC and C&G produce guidelines or teachers' books to accompany their syllabus schemes. In both cases, allusions made are similar to some of the key technology concepts. We are concerned that some tutors may teach their specialist units without reference to this supporting material. Several suggestions are made:

- The guidelines or teachers' books should be modified to emphasise and advocate the key technology concept approach.
- Greater reference should be made, in syllabuses, to this supporting material and the necessity for incorporating its aims in the teaching and learning strategies.
- A brief synopsis of the main relevant points from the guidelines should be incorporated in syllabus units.
- When revalidation of courses takes place, the obligation on teachers to read and respond positively to the guideline materials should become part of the course management process.
- Course monitoring procedures should encompass all course elements concerned with the key technologies concepts.

We had suggested that the critical factor in the espousal of the key technology concepts is the ability to change attitudes. This cannot emerge from a syllabus nor be taught in a conventional way. We can only change attitudes in our students when our own attitudes have changed. The answers lie in the *teaching and learning strategies* we adopt, and the changes will be dependent on well-directed and relevant *staff development*. We address these crucial issues in the following chapters.

In its consultative paper *Science Education 11-16* [8], the Secondary Science Curriculum Review (SSCR) states:

> It is widely accepted that many current examination syllabuses ... are overloaded with content and tend to be out of date, too narrow and lacking in much that is directly relevant to adult and working life. Syllabuses, and the way they are taught and examined, tend to create a pressure to learn and recall facts, concepts and principles, but restrict the application of knowledge to well-known and often contrived situations. Students are rarely required to analyse and evaluate their store of knowledge or to apply it in practical situations to solve realistic problems.
>
> (Together with other problems) these factors contribute to the quantitative problem of young people qualifying for careers in science, technology and engineering and may also affect attitudes held by many adults towards science, technology and industry.

These statements were made mainly in relation to the General Certificate of Education (GCE) and the Certificate of Secondary Education (CSE) and helped shape the pioneering concepts underlying the General Certificate of Secondary Education (GCSE). However, the strictures ring remarkably true for many qualifications offered today, right through into higher education. In previous sections of this report we have registered our belief that syllabuses are overloaded with narrowly confining content which is frequently obsolescent before the documents are published, so fast is the pace of technological change. Here we are concerned with, using a phrase from the paper:

> Syllabuses, and the way they are taught ...

The move towards learning strategies such as student-centred assignments is causing some disquiet in industry and the outside world at large, probably because of insufficient or inadequate explanations. It is hoped that this report will help allay these fears by explaining that it is attention to a wide range of interdisciplinary basics, via such methods, that will provide the foundations upon which the specialised superstructures may be built. Crucially, the key technologies concepts, as integral parts of those foundations, will allow pupils and students to take in their stride the twists and turns of emerging technologies and allow migration across conventional discipline boundaries. Additionally, the process is designed to create a new climate of attitude and make participants conscious of the economic consequences of decision making. We do not suggest that the concepts will be easy or simple to implement, but careful forethought and planning can overcome many of the difficulties predicted in the staffroom. This is where the change of attitudes has to begin. It is much easier to change the content of a syllabus than the way it is taught. To change both simultaneously, which is what we are advocating, will require a high degree of confidence and surefootedness in the management of change.

Of the syllabuses analysed, it is those from BTEC which have faced these difficulties. We attempted to tackle them, if not

directly through the units then at least in the accompanying guidelines. Furthermore, as we reported in a previous section (Chapter III), specific units are being formulated which will major on the main aspects of key technologies, introducing the student to economic awareness and the wider ramifications of the technological decision-making process. As indicated in the Teaching and Learning Process and Assessment section of the BTEC *Engineering Guidelines*[7]:

> By using appropriate integrative teaching, learning and assessment strategies, course teams will enable students to see how the various parts of the course relate, as well as to appreciate the course's relevance to work and to engineering applications. This will encourage the development of durable, transferable skills and facilitate the achievement of course aims.

Stressing that teachers must work as a co-ordinated team, the guidelines highlight anticipated difficulties:

> This will entail a significant *change of attitude* for those staff who have been running courses with comparatively rigid subject boundaries and more traditional teaching methods.
>
> (Our emphasis)

The BTEC guidelines stress the importance of core skills and how these must be developed in students if the course is to be successful and of continued usefulness to industry. The student's core skills:

> relate to engineering knowledge and to intellectual and personal development, including the ability to transfer learning to new situations. Experiential learning, through practical task-based activities using assignments and case studies, is a good way of developing these skills: it allows the skills and knowledge acquired in one or more units to be integrated and ensures that they are applied in situations which are vocationally relevant.

We would add that we believe it is also one of the best ways to transfer to the student the key technologies concepts and to **change attitudes of both staff and students.**

When the research team began to consider integrative student assignments, it soon became evident that even in one college there was lack of uniformity; departments (and in some cases sub-groups of departments) had evolved their own style of approach. This applied not only to assignment formats but also to the process by which assignments are created. After consideration of various formats, including suggestions from the project steering group, the team proposed a flexible framework (Figure 4) which can accommodate the varied requirements of this report and, we believe, most others in FE and HE. Every piece of the framework is important and, while individual interpretation and shaping for a given situation are to be encouraged, no item should be omitted. It should also be remembered that students should work in teams, not in isolation, because this helps replicate the real-life situation.

GENERAL FORMAT

- TITLE
- AIMS
- STATEMENT OF REQUIREMENT (including a list of objectives)
- PLANNING
- IMPLEMENTATION/PRODUCTION
- EVALUATION
- PRESENTATION

The assignment will be accompanied by notes for the tutor indicating CORE TOPICS which the assignment is intended to cover plus a list of RELATED TOPICS in other disciplines. Signposts to KEY TECHNOLOGY CONCEPTS will be included at relevant points.

Figure 4 – Integrated cross-modular student assignment

Based upon this experiential learning approach, the research team has evolved a generalised format for integrative cross-modular student assignments. While the detail will vary from one application to another, the format appears to hold up well in all areas to which it has been subjected by the team:

- Physical science;
- Biotechnology;
- Microelectronics;
- Mechanical engineering.

While the general format might be used with modifications to suit a different task area, it is essential to remember that it is predicated on two axioms[10]:

- a wholly student-centred approach;
- the 'system' or 'whole-to-part' approach.

If either of these pillars has been removed, *de jure* or *de facto*, then the assignment will not and cannot achieve its purpose with regard to the key technology concepts.

In considering the general assignment format, we would make the following suggestions:

Title Use a title which gives the student immediate accessibility to the subject. Familiar words will dispel alienation. Ensure that the title is not subject-restrictive; remember this is a cross-boundary project.

Aims Keep the aims few, brief, unambiguous and readily understandable at the appropriate level. The subsequent project work done by students will depend crucially on their interpretation of the aims, as stated. This does not mean that students cannot ask questions relating to the aims, but rather that they raise questions concerned with the next item.

Statement of requirement (including a list of objectives) This is the point where flexibility of approach, personal interpretation, tutor judgement, subject requirements and student ability/level have to be taken into account. The first question to be raised must be: Who makes the statement of requirement? The second is: Who creates the list of objectives? There are cases where:

- both are within the assignment;
- the statement is within the assignment but students create the list of objectives;
- both are researched and written by students.

In our exemplars we have encompassed these possibilities. Nevertheless, we stress that where choice is possible it should always be exercised in such a way as to throw the maximum onus onto the students. Only in this way can we attempt to replicate real-life situations. A statement of requirement without a list of objectives makes self-evaluation by the students and final evaluation by the tutors exceedingly difficult. Therefore, each assignment should include realistic objectives in the pre-planning process.

Planning With the exception of a few signposts, for example drawing students' attention to safety considerations, the planning of the assignment should be within the students' purview. Indeed, it is the approach to the planning process which will say most for students' ability to succeed in a real-life situation.

Implementation/production Both words are used to take account of projects which could lead to a final product or artefact, and those whose essential conclusion is a process. Again, signposts are permissible but, as in the planning stage, the work must be that of the students; any help sought should be reflected in the marking scheme.

Evaluation The list of objectives at Stage 3 is to enable students to evaluate the final product or process against the markers specified. Without these the evaluation exercise becomes woolly and imprecise. They set students and tutors a series of targets against which the outcomes of the assignment may be judged objectively.

Presentation This will depend upon the type of project, but an amalgam of the following, in varying proportions, should satisfy most cases:

- demonstration of an artefact;
- demonstration of a process;
- written report;
- verbal report;
- question and answer session (by tutors, peers or by both).

Core topics, related topics, key technology signposts The student assignment may be accompanied by written notes for tutors. These should include a list of core topics the assignment is intended to cover and a list of related topics in other disciplines. For example, a project to simulate traffic lights must have as a core topic the control of vehicles on the road. However, one in eleven of the male population is red-green colour blind, so vision defects become related topics within the province of

biotechnology. Similarly, queuing phenomena are related topics in mathematics and statistics. In writing a student-centred assignment, judgement should be exercised in deciding whether to include the core and related topics in the students' brief, or keep them within the tutor's notes to be teased out by the student at the statement of requirement stage. Much will depend on the level of the assignment and the ability of the students. Certainly, during the early period of implementing the new concepts, key technology signposts should be offered to the student either verbally or in the brief.

The research team believes that there is no single method. On the contrary, there will be benefit from using a variety of processes provided all parties work towards the implementation of the key technology concepts.

For those concerned with project work in schools, we recommend the study of a recent publication by the Assessment of Performance Unit, entitled *Design and Technological Activity: A Framework for Assessment*[11]. This considers the difficulties encountered in understanding design and technological activity and explains its process and purpose at school level. It provides an interactive model of design and technology, considers the content of the activity, and reports approaches to monitoring which are being used in a national survey of 15-year-olds during 1988.

A statement from the Engineering Council in conjunction with the Society of Education Officers, *16-19 Education and Training*[12], said:

> We should ensure that young people are motivated, able to reason, self-sufficient, literate and numerate, good communicators, able to work in teams and have the skills for solving problems.

We believe that programmes of integrative assignments, structured in the ways we have advocated earlier, will go a long way towards achieving the admirable goals set for young people in this statement. Nevertheless, colleges have a lot to learn from good school practice. We have had cause to say before, in this report, that the key technologies concepts are more evident at the primary level than elsewhere in the education spectrum. Indeed, in the same statement[12], the joint sponsors make the point that (in terms of to 16- to 19-year-olds):

> Whatever new system comes into being should build on the problem-solving approach used in primary schools and progress from a core curriculum and technical and vocational initiatives pre-16.

One initiative being taken up by a number of schools is the concept of enterprise projects. Different schemes take different names, but the basic idea is to create a company or enterprise which makes a product or supplies a service. The Mini-Enterprise in Schools Project has spawned 2000 mini-enterprises during its first year (1986/87). Its ultimate aim is the involvement of every secondary school in the country. In launching phase two of the project, Lord Young, the Secretary of State for Trade and Industry, said:

The aim of the project is not to encourage all young people to set up businesses as soon as they leave school. There is a real need to encourage youngsters to be more enterprising in their outlook on life in general, and in particular in their outlook in terms of the world of work.

The National Westminster Bank is supporting the project with a grant of £40 to each school, together with a low-interest loan of up to £50 for each group enterprise. A crucial factor which increases markedly the parallel with a real-life situation is that each group must make a convincing case to the manager before the funds are released. It is interesting to note what groups and schools do with any excess income over expenditure (if any) from their enterprises. Some give it back to the school for projects which can otherwise not be financed. Others donate to charity at home and in the third world. Thus, staff concern that the schemes will spawn profit-hungry yuppies is dispelled by these examples of community co-operation. What mini-enterprises do for students is provide an opportunity to create or increase:

- motivation;
- ability to reason;
- self-sufficiency;
- literacy and numeracy;
- communication skills;
- ability to work in teams,
- skills for problem solving;
- responsibility for decisions;
- knowledge of accounts and bookkeeping;
- skills in planning and forecasting;
- a yearning to research;
- skills in the design process;
- an understanding of quality control issues;
- marketing instincts;
- social responsibility.

It is time colleges took all these considerations on board; some do, but not nearly enough. Any school or college wishing to set up a mini-enterprise, an industry-based initiative or simply introduce enterprise into the curriculum should contact one or more of the following organisations:

- Mini Enterprise in Schools Project, Centre for Education and Industry, University of Warwick, Westwood, Coventry CV4 7AL. Tel: 0203 52391.
- Young Enterprise, Robert Hyde House, 48 Bryanston Square, London W1H 7LN. Tel: 01-724 7641.
- Schools Curriculum Industry Partnership, Newcombe House, 45 Notting Hill Gate, London W11 3JB. Tel: 01-229 1234.
- Entrain, Redlands, 3-5 Tapton House Road, Sheffield S10 5BY. Tel: 0742 670522.

The key technologies concepts cannot simply be bolted onto existing courses of study; they must pervade the entire curriculum structure and delivery strategy. To support their introduction, there must be staff development of teaching and non-teaching staff. We are seeking not only a broader curriculum, but also the introduction of interdisciplinary and innovative aspects of study into syllabuses which have been treated as relatively narrow subject areas. Unless this mould is broken, the key technologies concepts cannot be introduced. If we are to change the attitudes of students, then clearly we must change staff attitudes first.

The FEU/Engineering Council joint paper[3] notes that:

> Engineering is a multidisciplinary profession and engineers and technicians use their technical knowledge alongside their management and business skills. Personal qualities are often as important as technical ability, especially as engineers and technicians are often formed into project groups. Teachers and trainers should help to develop engineers' and technicians' appreciation of the commercial, social and cultural aspects of their work so that they are able to communicate effectively with their colleagues from other professions.

The joint paper further notes that, to achieve these aims, skills and knowledge other than those narrowly associated with the particular science or technology topic under consideration should be included, such as:

> systems thinking, group working, economic awareness (including finance, marketing and business skills), the efficient application of modern design processes... It is a concept that should permeate initial education and training, and should be a basis for continuing education and training for technicians and engineers.

Perhaps the most obvious element of staff development required for the introduction of the key technologies concepts to teaching is the need to keep up-to-date with technological developments. Appropriate methods include attendance on courses, industrial exchanges, industrial secondments and research. However, 'how we teach' rather than 'what we teach' will be far more significant. Reasons include:

- Key technologies do not fit neatly into traditional subject pigeon-holes; they span the curriculum and hence require inter-disciplinary teaching approaches.
- They demand skills, of the student, which are not the narrow cognitive and subject-specific ones with which we have traditionally equipped them. These broader core skills include:
  - — working with others;
  - — decision making;
  - — problem solving;
  - — time management;
  - — communication;
  - — numeracy;
  - — information technology;

— self and peer evaluation;
— inter-personal skills;
— economic awareness;
— associated management and business skills.

- They will require us and our students to consider outcomes broader than technological ones, e.g. the environmental and sociological consequences of technological activities.
- They require students to see issues in broad terms before focusing on specific aspects (the whole-to-part approach), rather than studying individual components then building these up into a more complete picture of the process as a whole.
- By definition, new key technologies are constantly emerging and it would be impossible to introduce all. Education must therefore give students the skills to adapt to change and concentrate on fundamental principles which underpin the development of specialist expertise.

We are, then, asking students to develop new skills, attitudes and ways of looking at issues. This can only be achieved if staff, too, develop these characteristics with regard to teaching and students' learning by:

- being prepared to stray outside the traditional boundaries of subject areas;
- working in inter-disciplinary teams, in planning and delivering the curriculum;
- developing a whole new range of teaching/learning strategies which are integrative, which develop more than just cognitive skills, which create a positive attitude to change and, most important, which focus on the needs of the student;
- developing assessment strategies appropriate to cross-curricular assignments. Particular issues include the assessment of core skills and group work.

We have to recognise, too, that as students develop skills of self-evaluation and decision-making, they will no longer be content to be told what to do and how to do it. Staff will therefore need to develop skills in handling participative decision making and negotiation.

It is encouraging that other curriculum bodies are giving similar messages. BTEC, for example, is emphasising the use of integrative assignments and the development of core skills; the corner-stones of TVEI and the TVEI extension are a broad, balanced, relevant curriculum and student-centred learning; the Training Agency encourages the development of transferable skills in the Youth Training Scheme (YTS) and has a new initiative to develop enterprise in higher education. Curriculum developments, though, have to be underpinned by staff development, and this brings us back full circle. How can staff best be prepared for the changes outlined above? The answer must mirror the changes we are suggesting as appropriate for students. Staff development must focus on actual problems which face staff. It must be based on course-teams, be active, realistic, relevant, and prepare staff to cope with change.

In connection with this report, a one-day in-service training seminar was held at GlosCAT. The training programme and staff-development materials used form Appendix 3.

The implementation of the key technologies concepts clearly has implications for planning procedures within institutions and their consequent effects on resource provision, but this lay outside the original project brief. It would, however, be easy to opine the way we believe education and training should change, without considering the changes necessary to allow implementation and the extra (or different) concomitant resource provision. With the support of the project steering group, it was decided to consider these matters in addition to our main tasks.

The planning and resource implications of introducing key technology concepts into curricula were also addressed by the national conference associated with this project. The research team provided a number of signposts for delegates to consider as starting points. The syndicate work, and the discussion provoked in reporting back at the plenary session, elicited many other implications. The conference therefore succeeded in its twin aims of providing new horizons for the delegates and additional information for the subsequent report.

The outcomes of the combined deliberations of the research team and the conference are presented in signpost form, but no attempt has been made to establish a priority. We are not suggesting that the following points are exclusive of other considerations; far from it. However, attention should be given to all the pointers stated, else planning for the implementation of the key technologies concepts may well be incomplete and the consequent resource needs found to be inadequate.

ACCURATE IDENTIFICATION OF COURSE NEEDS

Those responsible for introducing the key technologies concepts into courses should analyse requirements under such headings as staff development, room/equipment resources, team teaching, and many others. Further signposts in this section highlight such considerations.

DEMANDS OF EXAMINING/VALIDATING BODIES

As examining and validating bodies alter course towards the key technologies concepts, so their demands will change. Indeed, they are already changing. All staff concerned with implementation (i.e. college management, course management, course delivery and course support staff) should be aware or made aware of these changes. Remember that the changes will not necessarily appear in the syllabus content. They are more likely to arise in associated guidelines or teachers' notes. The integration of such guidelines and notes with their syllabuses should be much closer than ever before and no member of the team should be unaware of the implications.

COURSE VALIDATION, MONITORING, REVIEW

While institutions have their own methods of addressing these points, the moment the emphasis shifts from syllabus content to teaching and learning strategies, these considerations become ever more important. In implementing the key technologies concepts, schools and colleges should reassess their validating, monitoring

and review procedures to ensure that they are capable of addressing the changes that will occur.

STAFF REVIEW, EVALUATION AND ASSESSMENT

Contentious issues cannot be shirked and the introduction of key technology concepts renders these considerations even more important. While specialist knowledge and skills are as vital as ever, key technologies demand flexibility of approach, changes of attitude, the breakdown of traditional subject barriers and the ability to integrate course structures across the curriculum. All these aspects should be encompassed in staff review procedures.

TEAM TEACHING, TEAM MEETINGS

Two important points arise here:

- Staff may be unfamiliar with team teaching or fail to understand the opportunities for integration of the key technologies concepts that it provides. This is an issue for team management and staff development.
- Team teaching necessitates team meetings, and this has resource implications. All team members need to be available simultaneously for the meetings and this has knock-on effects involving mechanisms such as common timetabling slots, averaging and student:staff ratios (SSR).

TIMETABLING, COMMON TIME SLOTS, AVERAGING

It is not just the demands of team meetings that affect these considerations. The move towards programmes of integrative assignments dictates a completely new approach to timetabling. For true integration, key members of the cross-curricular teaching team should be available to students during multi-disciplinary assignments. The same considerations apply to staff as otherwise apportionment of marks may go awry in continuous assessment procedures. Institutions are being encouraged to move towards common timetabling slots[13] in an effort to overcome some of the problems in team teaching. Recent changes in the terms and conditions of service of college lecturers could help, in that judicious use of averaging may ease the potentially adverse demands of team teaching on resources.

IMPLICATIONS FOR STUDENT:STAFF RATIOS

There may be problems involved with developing team teaching in a climate of tightened student:staff ratios and unit costs. Team teaching applies an increased staff input into a particular unit of the student programme and will result in reducing the student:staff ratio unless compensatory steps are taken. The ratio can be represented as a simple equation of the form:

$$\text{SSR} = \frac{\text{FTE students}}{\text{FTE staff}}$$

$$= \frac{\text{ACS} \times \text{ALH}}{\text{ASH}}$$

where ACS is average class size,
ALH is average lecturer hours per week,
ASH is average student hours per week, and
FTE is full-time equivalent.

To enhance the SSR value, the three elements in the equation can be manipulated; thus, ACS can be increased, ALH increased, or ASH reduced. In the context of team teaching, there is the possibility of increasing average class size to compensate for additional staff input. However, limits are set by physical constraints such as classroom area and the loss of value to the individual student of being taught in too big a group, even in a team-teaching situation. It may be possible to increase average lecturer hours towards the limits set by national agreements. However, it is likely that team teaching demands greater consultation between staff. Thus, expecting an increase in ALH may make unreasonable demands on members of teaching staff. If consideration is given to reducing average student hours, it must be understood that there are limits, depending on the nature and sophistication of the student group and on the subjects being studied. If hours are reduced too much, students will not have sufficient contact with staff, even in a team-teaching situation. Thus, by manipulating the factors which contribute to SSR, some limited compensation for increased staff input implied by team teaching can be achieved. However, it is unlikely that the improvement in student experience that arises from properly planned team teaching can be delivered at no additional cost. The quality and effectiveness of the learning experience has to be balanced against considerations of cost and economy.

LEA DELEGATION TO COLLEGES

In preparing schemes of delegation to colleges, as required by the Education Reform Act, local authorities are required to make decisions about units of resource, programme weightings, and weightings for mode of attendance. It is important that curriculum issues, such as those associated with the implementation of the key technologies concepts, are built into considerations of appropriate values to be entered in funding formulae. Values set at too low a level will discourage curriculum innovation and discriminate against certain modes of attendance. The advice contained in DES *Circular 9/88*[14] provides for the reflection of true cost and the effect of LEA policy on curriculum provision.

TEACHING STAFF DEVELOPMENT

Adequate in-service training must be a high priority in implementing key technologies. Planning well in advance will be the path to success, but tailoring development to individual staff members' needs can only follow thorough appraisal and review. The development required may well exceed anything attempted heretofore, but the introduction of key technology concepts is pioneering work and may well require the greatest re-thinking exercise encountered by many members of staff. Changing entrenched attitudes can be uphill work and accurately targeted staff development will be the shortest route to the summit. This amount of staff development immediately sets the provision alarm bells ringing. With financial devolution to institutions in the near future, a trade-off must be sought. It may be that extra staff development provision equals one degree lower temperature for a term. This type of equation will soon have to be tackled and solved throughout education. Why not make it part of the

planning process for key technologies sooner rather than later? (Staff development *per se* is addressed in Chapter VI).

SUPPORT-STAFF DEVELOPMENT

Non-teaching staff are a vital resource and should not be disregarded in the planning process. To do so with key technologies is inviting peril. Technical staff will not only be highly involved in the practicalities of increased student-centred activities, but will also need adequate explanations of the role and purpose of key technology concepts. Furthermore, as assignments become more cross-curricular, support staff will realise that their skills are insufficient and do not extend to what had been considered another department's problems. For example, the jargon clerical staff had learned to cope with by familiarisation over time will quickly multiply as assignment sheets cross discipline boundaries. Good management will ensure that they understand why, without having to ask. Local authorities have tended, in the past, to make little provision for support-staff development. Here is another opportunity to take advantage of the financial autonomy bequeathed by the Education Reform Act. Adequate forward planning is essential.

HANDLING INCREASED STUDENT FEEDBACK

Moving away from rigidly set examinations towards continuous assessment, programmes of integrative assignments and profiling necessitates an increased amount of student-produced material. The key technology concepts will depend crucially upon these moves and therefore provision must be made for handling more paper-based feedback and keeping accurate track of marks in assessment or profiling schemes. Wherever relevant, the introduction of new technology aids should be planned and encouraged, albeit with concomitant extra staff-development provision.

ROOM REQUIREMENTS

Already, institutions are finding that rooms specifically designed for traditional laboratory or practical work are grossly inconvenient when the change to assignment or project work is made. Heavy benches, fixed sites for sewing machines, or virtually immovable machine tools can render a potentially suitable space totally useless. Much rethinking of space application and allocation is required throughout education and the aim should be for increased versatility and flexibility. Technology is changing apace and the immutable dedication of space to today's skills will undoubtedly lead to otherwise avoidable expense tomorrow.

HARDWARE REQUIREMENTS

Thermionic valves featured heavily in the C&G syllabuses in 1980, whereas now students at a similar stage may well be encountering 32 bit microprocessors. Sometime in between they grappled with transistors. Next it will be the neuron-gate and biotechnology will be inseparable from logic circuits. Whether school, small FE college or large HE institution, the changes in facilities and hardware demanded by this technological progression are daunting. Project work, in comparison with old-style laboratory experiments, frequently needs increased

provision to satisfy the requirements of student groups simultaneously. The expense involved cannot be avoided, but improved amortisation, and co-operation between institutions themselves and with industry are paths which should be explored.

CO-OPERATION BETWEEN INSTITUTIONS AND WITH INDUSTRY

If we assume a college day of 10 hours (i.e. 9.00-12.30, 13.30-17.00, 18.00-21.00) and a college teaching year of 36 weeks, equipment is in use for a possible total of 1800 hours. In fact, equipment is available from 9.00-21.00, by staggering natural breaks in the day, and for up to (say) 50 weeks of the year. On this basis the use of equipment is possible for 3000 hours. This yields an amortisation ratio of only 60%. No industry would sustain such a low figure for its capital investment; why should education? (Incidentally, we have omitted the use of equipment at weekends, for externally funded activities, from the calculations. This not only improves amortisation but yields revenue as well.) With financial devolution, colleges will have to co-operate in the purchase and use of increasingly expensive capital equipment. Industry can help too by donating equipment, subsidising purchase and allowing on-site facilities to be used for demonstration and training. After all, the ultimate benefits are mutual.

PART-TIME AND GUEST LECTURERS

The single most expensive commodity in an educational institution is staff time. By and large, the salary bill accounts for 70% of the total expenditure of a college. As technology changes, staff can be helped to keep up to date by their own efforts and by a planned programme of staff development. But there are limits even for the most flexible minds. As an example we might take logic systems again, where the electronic gate approach is well established, well documented, well understood and adequately resourced. Already, sections of industry are edging towards optical systems with the attendant advantages of increased signal channels and relative freedom from interference (by espionage, vandals or electromagnetic effects). Developments mean that logic systems will soon be based on superconductivity devices or neural networks. We believe that such leaps in technological progression will have to spawn new relationships. Within institutions, the first-order way to clear these hurdles is co-operation across old discipline boundaries. Who has the optical knowledge? The physicists. Who can produce high-temperature superconductivity materials? The chemists. Who understands neural networks? The biotechnologists. Who wants to use logic circuits? They all do! So, in ten years time, who owns logic systems?

Outside institutions, the most up-to-date knowledge lies in industry; colleges must learn how to tap this potential and industry must be prepared to co-operate by providing part-time and guest lecturers. It will be to the advantage of both.

INDUSTRIAL LINKS AND SECONDMENTS

Industrial secondments tend to follow a one-way path, from education to industry. Many colleges have excellent relationships

of this type and academic staff (and ultimately their students) benefit from the period spent in the outside world. Much less frequently, industrial staff spend time on secondment to an educational institution; active steps should be taken to increase the number of such secondments. For all the reasons stated in previous sections, there would be great benefits in having industrial staff available in or to colleges as they seek to implement the key technologies concepts. We urge industry, in its own long-term interests, to heed this message and make staff available.

PART THREE

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Searching for instances of key technology concepts forming specific elements of learning programmes in schools may occasion some considerable frustration. It is unlikely that they would continue to be defined as 'newly emerging topices in Science and Engineering'[1] by the time the resources, training and role had been established that would enable their meaningful inclusion within the school curriculum. However, in creating a climate in which key technologies may be developed and exploited in further and higher education, schools undoubtedly have a major contribution to make.

A growing recognition of the central role of education in providing young people with the skills required to play an active part in a rapidly changing world, and the importance of such skills to the economy, promoted the 'Great Debate' of the mid 1970s and many of the curriculum innovations that have resulted, particularly in the secondary phase of education. Fundamental to these developments has been recognition that, unlike former vocational initiatives, the pace of technological change is such that specific skills are likely to be superseded in increasingly short timescales, indicating that it is by the development of transferable skills, attitudes and values that young people are most likely to be prepared for the everchanging demands that will probably be made of them in their future employment.

The General Certificate of Secondary Education (GCSE), which has superseded GCE and CSE as a single system of examining at 16+, has, among its central objectives, the requirement that all examined subjects provide a balance between knowledge and transferable skills, attitudes and values. Comparison of the National Criteria[15] for the 20 initial GCSE subjects indicates assessment objectives which require development of the following common process-based skills:

- analysis of situations or outcomes;
- identification, selection, evaluation, interpretation and application of relevant data;
- interpretation of evidence as a basis for making judgements;
- communication of information, ideas, opinions or conclusions in an appropriate manner.

Each subject area thus provides a context to which these common skills may be transferred, developed and applied in a manner relevant to the area of study. While subjects include some specific skills, there is a high proportion that are process based and readily transferable due to their relevance to other areas of study, for example:

> the skills of observation and recording, whilst being central to science subjects, are also processes used in, e.g., Geography, Home Economics, CDT and Art.

Thus the GCSE framework can be seen to support the ideas implicit in the concept of the key technologies by encouraging young people to develop the ability to adapt flexibly to new situations through applying appropriate transferable skills. The

degree to which syllabuses focus on a wide range of fundamental skills and processes, in addition to knowledge, further supports the key technology concepts where such fundamentals are seen as an essential element of the school curriculum, thus providing a broad base on which employers can accept responsibility for the peaks of specialism when the needs arise through formal or informal continuing education and training. The aims of GCSE subjects include attitudes and values, not all of which are translatable into measurable assessment objectives. The development of these, however, is seen as central to:

- the effective application of knowledge, skills and processes to practical situations;
- the ability to place the subject area in a broad context.

Reference is made in *A Call To Action*[1] to the length of time required to develop effective attitudinal changes and the value of providing a context in which these may be promoted within the school curriculum. GCSE courses in Craft, Design and Technology (CDT), and Home Economics exemplify areas of the curriculum that can provide such contexts. For example, the aims for CDT include:

- placing emphasis on promoting personal qualities likely to enhance the potential for innovation, through situations intended to promote curiosity, enquiry, initiative and ingenuity;
- encouraging the development of attitudes of co-operation and social responsibility and the exercising of value judgements of an aesthetic, moral and economic nature considered important in promoting positive attitudes to technology through a developing understanding of its social and economic impact.

While it will be a further three years before pupils who have benefited from a full five-year GCSE course have been assessed at 16, HMI has already reported on an observed increase in pupil motivation particularly associated with coursework elements of GCSE schemes. These are central to the philosophy of enhancing perceived relevance and identity with subjects through applying acquired skills and knowledge to real-world situations of particular interest to the pupil concerned.

While GCSE is concerned with the promotion of transferable skills, attitudes, values and perceived relevance within the subjects studied, the Technical and Vocational Education Initiative (TVEI) has explored the optimal incorporation of work-related skills within initial full-time education and has focused on achieving overall balance and breadth within the curriculum for pupils in the 14-18 age range. The scheme, which began in pilot form, is now available to all schools wishing to start during the period 1988-92, providing the curriculum they propose conforms to TVEI criteria, developed from Government policies outlined in *Better Schools*[16]. In addition to insistence that schemes should address the issues of relevance, and appropriate levels of expectation, help with curriculum breadth and balance was provided by guidelines indicating that the curriculum for each pupil should include an adequate time for:

- mathematics;
- English;
- physical education;
- elements from humanities and the arts;
- religious education as governed by law;
- access to a foreign language,

and, of particular relevance to this paper:

- a balanced science;
- the development of economic awareness;
- participation in practical and technological work in a number of subjects, not least science.

Inevitably, the TVEI framework has encouraged a variety of approaches, both by LEAs in developing authority schemes and in the individualistic responses of schools governed by their own needs and resources. Common features that have emerged to aid delivery are:

- the development of a wide range of teaching and learning styles;
- information technology across the curriculum;
- the development of specific programmes to deliver technology;
- the development of formative profiling;
- a planned programme of work experience;
- a programme of personal and social education;
- a programme of careers guidance.

Her Majesty's Inspectorate (HMI), in the series of discussion documents *The Curriculum from 5 to 16*[17], highlighted the potential for initiatives such as TVEI to enrich the curriculum and rectify a suggested imbalance by making the curriculum:

> more practical and relevant to adult life and by causing schools to expand their range of approaches to teaching and learning. Specifically, pupils of both sexes and all abilities can benefit from work which enhances their understanding in the scientific and technological areas of learning through subjects such as business studies, craft design and technology, computer studies, science and maths.

In the document HMI suggests that certain elements should be woven into the curriculum, which should involve all pupils in the following areas of learning and experience:

- aesthetic and social;
- linguistic and literary;
- mathematical;
- moral;
- physical;
- scientific;
- spiritual;
- technological.

A second and complimentary perspective suggested was that identified as:

> elements of learning: the knowledge, concepts, skills and attitudes which all schools should seek to develop in their pupils.

Within the discussion of these elements of learning, HMI outlines a comprehensive range of skills that schools should develop, which include:

- communication, observation;
- problem solving;
- physical and practical, creative and imaginative;
- numerical, personal and social.

HMI wishes to see TVEI and other initiatives as positive agents to enrich the curriculum through contributing to the breadth and balance outlined and not impoverishing it by emphasising particular areas to the detriment of others. This is acknowledged in GlosCAT's TVEI Extension Scheme which considers the TVEI requirements within a wider framework and includes all HMI areas of experience and elements of learning as a basis for the GlosCAT 14-18 Curriculum Initiative. Suggestions that key technologies are dependant on multidisciplinary approaches implies concern regarding rigid subject boundaries that is also echoed within schools as curriculum patterns are sought that will promote the notions of transfer and relevance to the world of work. The topic approach, commonly regarded as an effective teaching and learning model in primary schools, is an excellent example of the potential of thematic approaches to encourage activity that transcends traditional subject or disciplinary boundaries. Within this model, teachers often use the stimulus of a visit or an idea developed from literature to initiate activity in a wide range of curriculum areas. While such an approach may be considered more appropriate within the primary sector, where a particular group of children is taught mainly by one teacher, there are many successful examples of secondary schools applying the cross-curricular project model. Such an approach may involve an interdisciplinary team of staff organising a week-long project to heighten pupils' awareness of third world or local environmental issues, or may involve pupils in longer projects within a regular timetable allocation, as part of an enterprise scheme designed to provide experience of developing and running a small company (see Chapter V).

The increase in project work associated with GCSE syllabuses provides increased opportunities to approach subject areas through topics rather than teaching narrow sub-divisions of subjects. Opportunities abound to involve relevant materials from across traditional boundaries, in subjects that include a final major project. The current Certificate of Pre-Vocational Education (CPVE) for post-16 students has already addressed the desirability of working across subject boundaries by providing the opportunity to study 10 core topics through activity in vocational areas such as:

- production technical services;
- distribution services to people;
- business administration.

However, GCSE and 'A' level courses of a cross-curricular nature seem unlikely to be widely available in the near future, the most promising developments seemingly directed towards a wider range of activity pursued from a particular subject base.

In July 1987, the Secretary of State for Education published a consultation document, *The National Curriculum 5-16*[18], which holds great significance for the notion of schools providing an educational experience in sympathy with the concept of the key technologies, as it initiates a process that will conclude with the announcement of a common statutory curriculum for all primary and secondary schools within the state sector. The document outlined plans to develop a curriculum structure centred on:

Core subjects:	English, mathematics and science.
Foundation subjects:	Technology; geography and history; a course including art, music, dance and design; physical education; and a modern foreign language in secondary schools.

It was proposed that the foundation subjects should take up most of the curriculum time in primary schools and 30% or 40% in secondary schools, dependant on whether pupils chose to study a single or double science award. In secondary schools, it was suggested that in years four and five, foundation subjects would each account for 10% of curriculum time, providing an opportunity for pupils to choose subjects other than those within the core and foundation categories. While there is an obvious danger that such a model could perpetuate rigid subject boundaries, particularly in secondary education, cross-curricular themes are to be built into the structure, be taught within the foundation subjects, and provide the vertical components in a matrix of horizontal core and foundation subjects. It is encouraging to note that while some modification of GCSE syllabuses may be needed, especially in view of the Task Group on Assessment and Testing (TGAT) recommendations[19], it is envisaged by the Secretary of State that the National Curriculum should incorporate and develop the successful principles of the GCSE and TVEI initiatives. Both these have been highlighted as having features supportive of the philosophy of key technologies. The Science Working Party, in its interim report (published Dec. 1987), stated its intention to identify and build on existing good practice. (This intention seems to have been realised to a large extent in the group's final report, published in August 1988 as *Science for Ages 5 to 16*[20]).

Recognition of the importance of increased levels of technological awareness, understanding, knowledge and skills among the nation's future citizens was confirmed by the inclusion of technology as a foundation subject within the National Curriculum for all 5- to 16-year-olds. This was reinforced by the Secretary of State in his announcement of the Curriculum Working Group for Design and Technology on 29 April 1988[21], when he said:

> Design and technology are vital areas of the curriculum. They are of great significance to the economic well-being of the country. I believe it is essential that we press ahead quickly in establishing them within the national curriculum.

Of particular relevance to the key technologies concept are the following points within the remit to the working party:

- that the area of study is focused on processes through which needs are identified, and relevant knowledge and understanding, both subject specific and pan-curriculum, are applied to designing, making, testing and evaluating solutions;
- that pupils should learn about modern materials and technologies used in the industrial and commercial world;
- that pupils be prepared for the world of work by learning how to:
  - — work in teams as well as individually,
  - — understand the importance of functional efficiency, quality, appearance, marketability, and the importance of working within financial and technological constraints.

Recognition is also given to the contribution made by technology to other areas within the curriculum and the input that these subjects, in turn, make to technology, leading to the suggestion that the technology component of the curriculum may be introduced as:

- a free-standing timetabled subject;
- a programme co-ordinated from identified technological elements in a range of subjects;

or

- a combination of the two approaches.

While it has only been possible to address a number of the issues raised by the concept of key technologies and their relevance to schools, it is clear that there is much in an embryonic or developmental stage that actively supports the key technology concept. While this is encouraging, there is no room for complacency for, as with all educational development, there is an inevitable lag between the time enthusiasts get involved in developmental work and the general and effective introduction of resultant schemes across the whole school population. The most valuable role for schools is considered to be the formulation of an appropriate foundation upon which further or higher education, and future employers, may develop specific expertise. However, the key to developing the appropriate attitudes in young people is to first engender these attitudes within those who are to promote the message.

Thus, if schools are to play this vital role in promoting the concept of key technologies, it is essential that strategies for the effective training and resourcing of teachers is urgently considered if the concept is to be given credibility and momentum.

APPENDICES

SYLLABUS ANALYSIS

Syllabus title Science

Examining / validating body BTEC

Level First Certificate/Diploma

KEY TECHNOLOGY ASPECTS					CURRICULUM ASPECTS			
SYLABUS/ SECTION	**TECHNOLOGY STATUS**	**ECONOMIC EFFECTS**	**EVOLUTIONARY EFFECTS**	**APPLICATION AREAS**	**PRE-REQUISITES**	**CONTENT**	**RESOURCES**	**TEACHING/ LEARNING STRATEGIES**
Anaerobic respiration	Fermentation Old: - food technology - wine/beer technology New: - biotechnology	- cost & time saving - less animal research work required - large-scale production - enables more people to have treatment	Biotechnology - production of new chemicals, drugs, etc.	Medical/biological fields - genetic engineering - drugs - hormones - proteins - enzymes Industrial applications - precious metal reclamation - gold, silver, copper	Basic level: - Biology - Chemistry - Physics	Anaerobic respiration	Demijohns/ fermenters	Theory 30% Assignment 70% (inclusive of practical work)
Enzymes	Old: - biochemical assays - immunoassays New: - industrial application	- cost and time saving - product improvement - increased industrial efficiency	- Food technology - Industrial effluent treatment plants (pollution control)	Enzymes adhered to inert exchange columns - allowing substrate/effluent to be acted upon by enzymes as they pass through column	Basic level: - Biology - Chemistry - Physics	Factors affecting enzymes - rate of reactions (kinetics)	Normal laboratory equipment For advanced work spectrophotometers UV/visible	Theory 30% Assignments/ practicals 70%

No references to key technology concepts found in unit

1. **Electronics**
2. **Mechanical and production engineering**
3. **Biotechnology**
4. **Physical sciences**

1. ELECTRONICS

1.1 DEVELOPMENT OF ASSIGNMENTS

A team comprising four to five members of staff from various disciplines meets for preliminary discussions under the guidance of the team leader for the programme of integrative assignments (PIA). One member of the team is from the area of general and communications studies. Suggestions are analysed in terms of aims and objectives and how they would fit into the overall PIA scheme. For example, account is taken of subject areas, level and prior knowledge required by students.

Once approved in principle, the originator develops the assignment into an acceptable manuscript form which is presented at a subsequent meeting and discussed and modified as required. When finally approved by the team, it is wordprocessed and added to the bank of integrated assignments on file.

All assignments are reviewed periodically and modified where necessary in the light of experience and changes in technology.

One of the roles of the general and communications studies team member is to highlight the common-core skills and, in particular, those that are to be tested in the particular assignment. The subject specialists ensure that the assignment is capable of extension into a wide range of subject areas and related topics in other disciplines. Hence, at the end of the course, the team can be satisfied that core skills, common skills, specialist subject matter and related topics have been developed and tested in line with BTEC guidelines and the key technology concepts.

In designing the specific assignments that follow, the whole-to-part or systems approach was used. Students learn to consider the system as a whole before becoming involved in detail. The assignments are also designed to be flexible, in terms of complexity, and have scope for subsequent updating. Thus they can be used by students at various levels in their training, and have currency for a reasonable length of time.

The chronology for a particular cohort might run as follows:

FIRST YEAR

First term	Power supply to specification
Second term	Binary counter to produce traffic-light sequence

SECOND YEAR

First term	Microprocessor-based system (software replaces hardware)
Second term	Power electronics to control lights (for either system)

Student-centred learning is intended throughout the assignments and hence a substantial understanding of current technologies is necessary. It is also important to highlight and compare the advantages and disadvantages of the choice of systems and components from beginning to end. The assignment should allow consideration of many other factors, for example social implications and economic awareness. According to the level of the assignment, these can be signposted in the students' brief or elicited by them during discussions in the early stages of their work. Such considerations could include:

- male red-green colour blindness;
- time delays causing frustration and thereby accidents;
- light intensity varying with ambient conditions;
- aesthetic considerations.

Technically, the assignments should allow the development of systems as diverse as a simple set of untriggered lights for roadworks, through pelican crossings for the blind, to city highways with anticipatory light systems for large traffic flows.

1.2 POWER SUPPLY ASSIGNMENTS

AIMS

To design, build and test a boxed d.c. regulated power supply incorporating a full wave bridge rectifier, smoothing circuit and regulating circuit.

STATEMENT OF REQUIREMENT

To determine the full specification the assignment staff should be consulted.

Student task

Request in writing, by a formal letter, the specification of the power supply, obtaining sufficient information to design the circuit and give a total costing of the final product, based on components available from appropriate catalogues. Ascertain the date by which the final product must be produced. From the reply, create a list of objectives to be achieved.

Assessment point

- Core skills;
- planning;
- communication;
- organisation.

PLANNING

To plan the design, construction, testing and reporting phases of the assignment.

Student task

- Draw appropriate diagrams (of circuit, its layout and its box).
- List components and test equipment required.
- Make brief notes based on theoretical background of rectification, smoothing, regulation and dummy load (list references).
- Decide on tests to be carried out.
- Plan the type of report to be presented.

Assessment Point

- Core skills;
- planning;
- technical safety aspects;
- team work.

IMPLEMENTATION AND EVALUATION

Student task

- Construct the circuit.
- Test the circuit.
- Enclose and finalise the constructing and testing procedures. *Note*: Tests should include diode characteristics, output voltage waveform with rectifier only, with smoothing added, with smoothing and regulation. A regulation characteristic should be produced.
- Check your product against your list of objectives.

Assessment point

- Core skills;
- problem solving;
- implementation and evaluation;
- organisation;
- communication (keeping laboratory log book).

PRESENTATION

Student task

- Prepare an assignment report from the log book record, add comments and conclusions, and include a final costing of the assignment.
- Be prepared to answer questions verbally on the assignment.

Assessment point

- Core skills;
- communication/evaluation.

Core topics	Related topics
Specifications Communications Planning/organisation Design/construction Circuits Enclosures Testing/reporting	Power supplies are used throughout industry, and in domestic and office equipment. Virtually every item of equipment involving electronics incorporates a power supply.

1.3 TRAFFIC LIGHT CONTROL ASSIGNMENTS

AIMS

To design and test a traffic light control system based on sequential logic circuits.

STATEMENT OF REQUIREMENT

The student group is to research the following points from which they must produce a list of objectives to form the specification to be agreed by the client.

Student task

To consider:

- application envisaged for the unit;
- TTL or CMOS family selection;
- cost;
- unit size;
- interface for lamp unit;
- product specification.

PLANNING

Student task

- designate areas of responsibility within group;
- draw an overall block diagram;
- plan time and design strategies;
- design the unit to the specification;
- estimate cost and time.

Assessment points

- Planning;
- initial design and theory;
- final design results.

PRODUCTION

Student task

- Breadboard design and construction;
- initial test results;
- final test report;
- suggestions for housing unit.

Assessment points

- Type of construction used;
- intermediate/final test results;
- unit housing.

EVALUATION

Student task

- Have all the objectives been achieved?
- Identification of areas where redesign is necessary and the reasons.

Assessment points

- Logical thought processes;
- communication skills.

PRESENTATION

Prepare a written report covering the objectives, including any problems or difficulties encountered and how they were overcome. Be prepared to demonstrate the results of your assignment and answer verbal questions.

Assessment scheme

Specification	20
Planning	30
Production	30
Evaluation	10
Presentation	10

2. MECHANICAL AND PRODUCTION ENGINEERING

2.1 DEVELOPMENT OF ASSIGNMENTS

In the past, assignments were created by individual members of departmental staff. However, in view of the cross-curricular nature of BTEC requirements and the efforts to introduce the key technology concepts, a course is now involved. The process of developing a new assignment follows the pattern:

- total course appraisal followed by a study of individual units;
- identification of course themes, e.g. quality, systems, materials;
- selection of a theme by a member of the team, around which to sketch the outline of an assignment;

- discussion of the sketched outline by the team as a whole, with the creator adopting a sales attitude by trying to include in his package elements of others' subject areas;
- identification of the following elements, using a proforma, when an idea is agreed:
  - technical subject coverage,
  - BTEC unit titles and topic areas,
  - core themes,
  - common skills,
  - resources required;
- writing of the body of the assignment;
- submission of the total assignment to the team, making modifications if necessary, and giving approval;
- evaluation of the assignment following implementation, refining as required, and finally placing in a bank of student assignments.

2.2 COMPUTER-AIDED MATERIALS TESTING ASSIGNMENT

AIMS

- To develop the structure of a solution to a problem;
- to give an appreciation of the use of computers in engineering;
- to introduce the interfacing of analogue transducers with the computer;
- to work together as a team to solve a problem.

STATEMENT OF REQUIREMENT

A computer program is required, which will monitor the force and extension of a standard tensile test for mild steel. The program should determine the values for modulus of elasticity, yield stress, ultimate tensile stress and percentage elongation.

SPECIFICATION

Students are to work together as a team which must:

- identify the problem specification by questioning the 'client';
- collect all relevant information;
- create a list of objectives.

Common skills

- Questioning;
- collecting data;
- communication.

PLANNING

Working as a group, students should:

- devise a solution in modular form;
- allocate a student or small group to a module.

Common skills

- Working with others;

- problem solving;
- planning.

IMPLEMENTATION

Students should work together to:

- co-ordinate the implementation of the full program;
- carry out suitable tests using the program.

Common skills

- Problem solving;
- implementation and evaluation.

EVALUATION

Working on their own module, students should devise a methodical sequence of tests to ensure the module works according to the specification.

When program modules are brought together, students should evaluate the program against the customer's specifications and objectives. Any shortcomings should be corrected either by modification of the program or renegotiation of the specification.

Common skills

- Evaluation;
- working consistently to a plan.

PRESENTATION

Each student should submit a report which:

- contains the problem specification and objectives;
- contains the structure of the program;
- contains the algorithm for their module;
- contains the data table for their module;
- contains a list of inputs and outputs for their module;
- contains a program listing for their module;
- contains a sample of the program output;
- contains a diagram showing instrumentation used;
- highlights any problems encountered and explains how they were overcome;
- indicates to what extent the objectives have been met and the specifications fulfilled;
- contains a statement as to why it is important for a company to have a copy of the results.

Each student should be prepared to answer questions on the assignment.

Common skills

- Communication;
- self management and organisation.

Core topics	Related topics
Computing	Data collection
Materials testing	Statistics
Instrumentation	Quality assurance
	Product liability
	Social implications (unskilled workers)
	Computer integrated manufacture

3. BIOTECHNOLOGY

3.1 DEVELOPMENT OF ASSIGNMENTS

Assignments are developed by a cross-curricular course team using two key approaches:

- wholly student centred;
- whole-to-part or systems method.

The nature of any particular assignment will depend upon the following criteria:

- the theme of work for the week;
- core science, supplementary science and related objectives;
- the industrial visit to be undertaken.

During the first term, assignments are set weekly. Criteria 1, 2 (core science objectives only) and 3 tend to dictate the format of integrative assignments.

The course team will decide upon the type and nature of an industrial visit suitable for the core science objectives. This visit may be:

- a general one where students report back on aspects such as:
  - career opportunities,
  - working conditions,
  - structure of the industry,
  - quality control;
- of a more specific nature, where students report back on:
  - scientific methods/assays/techniques,
  - apparatus and materials used,
  - large-scale plant processes,
  - quality control/testing.

In the latter case the course team might consider which objectives (core science, common skills, practical skills) could be covered in an integrative assignment which complements the industrial visit. This approach ensures that, for one or more of the following, the assignment:

- is based on a realistic situation;
- simulates the type of work students would expect to be doing in industry;
- is based on methods/assays/chemicals/apparatus used in industry;

- is based on industrial products;
- is integrative in that more than one task is involved (However, while it may not be possible to integrate biology, physics and chemistry, information technology and communication skills should be included in all assignments.);
- complements the experience gained from preparatory tasks/ practical work/literature research;
- covers and reinforces certain core science objectives which may or may not have been covered by the common theme study work (in other words is treated as a teaching strategy);
- leads to supplementary exercises such as social aspects (e.g. pollution), economic considerations, and so on.

Assessment will depend on the nature of the assignment; assessment criteria should include:

- planning;
- decision making;
- teamwork;
- bench organisation;
- practical skills;
- literature research;
- safety;
- communications skills.

The integrative assignments for terms two and three are set over a longer period of time, e.g. two to three weeks. Their format will be dictated by criteria 2 (supplementary science and related objectives) and 3 (the industrial visit).

4. PHYSICAL SCIENCES

4.1 DEVELOPMENT OF THE MILK ASSIGNMENT

For BTEC National Award courses in science there is a small course team comprising:

- chemist
- biologist
- physicist/mathematician
- common skills specialist

} all moderately competent in computing

At a meeting of this group, the chemist mentioned a lecture by a public health inspector where a method of detecting milk dilution by measurement of freezing point was discussed.

The team decided that the topic of 'milk' was an appropriate common theme. The members contributed as follows:

Chemist:	Calcium content — Group II detection — Flame and A.A. instrumentation
Biologist:	Production of milk by the body — effect of bacterial contamination — study of lifetime of food products — use of agar plates

Physicist:	Sensitive thermometry in a narrow range of temperatures — types of thermometers — resistance thermometry — transducers such as a thermistor — bridges — signal size — need for amplification?
Mathematician:	Accuracy — reproducibility — errors — exponential laws of thermistors — display methods of results of a number of readings — computer use
Common skills:	Calcium — pregnant women/old age — launch of a new product: High Calcium Milk — market research — economics.

Initially no time scale was set for the assignment but, as it evolved, the decision was taken to create dual assignments:

- one open-ended;
- the other tightly controlled on time.

Both were then available for day-release and full-time students, as required. After implementation, evaluation and modification, they were deposited in the assignment bank.

4.2 MILK ASSIGNMENT

AIMS

- *Science*: to study the testing of milk for dilution, using a number of different techniques, and hence acquire practical experience of laboratory test procedures.
- *Common skills*: to acquire experience of group working, library skills, report writing and critical appraisal.

STATEMENT OF REQUIREMENT

Setting for the practical aspects of the assignment:

A farmer accidentally dilutes milk with water used to flush the milking system. Quality control at the dairy will discover this dilution by determining the freezing point of the milk, which requires an accurate temperature determination within a very narrow range of temperature.

PLANNING

Work required from student groups:

- the ability to carry out tests for bacteriological contamination;
- description of the cause of milk secretion and collection on the farm;
- as alternative methods of detecting dilution, the determination of:
  - fat content,
  - calcium content (example of Group II metal),
  - protein content;
- choosing a thermistor for the temperature range;
- arranging a Wheatstone bridge for resistance measurement;
- transposing, through graphical techniques, the resistance into a temperature;

- estimating the errors involved in the determinations;
- recognising the steps required for the launch of a new product on the market, and hence:
  - — identifying target consumers,
  - — suggesting a questionnaire for interviews,
  - — writing a scientific information sheet for the launch of a high-calcium milk product;
  - — using as a vehicle to discuss nutrition, marketing and regulations (EEC);
- flame photometers tests for calcium content.

IMPLEMENTATION AND EVALUATION

An end report will be expected; this should give a critical appraisal of all aspects of the assignment.

Assessment scheme

Major skill areas/principal objectives:

- equipment/tests are the ones required;
- they are properly performed;
- group work utilizes the major areas of expertise of the group;
- task allocation is fair;
- critical self and peer appraisal occurs;
- all sources of possible information are tapped;
- report reflects the work put in.

Assessment criteria

- The group operated effectively.
- Individuals fulfilled their alloted tasks.
- The correct procedures were adopted.
- Results were accurately taken.
- The results were accurately processed.
- The broadest range of information possible was used.
- The report was presented adequately.
- Did any group member at any stage display excellence?
- Were safety procedures adhered to?
- Do any group members avoid specific tasks?

The criteria will relate to:

- legibility in a finished report or artefact;
- language use, either formal or informal, deemed appropriate by the lecturer;
- presentation, which will reflect the time spent or apportioned to the product;
- performance of individual students in group activities not falling below 75% or perceived average performance;

- the step-by-step marking system used for scientific parts of assessments (Expert information will be given to keep the group on track during the assignment.).

Assessment methods

- Observation;
- report reading — extra/omissions;
- viva;
- 'science' checking;
- notebook/logbook reading.

Assessment strategy

- Science;
- mathematics;
- computing;
- common skills.

Besides testing various scientific practical skills and procedural mathematical skills, it is hoped, through realism and relevance (e.g the financial loss of a tanker of milk), to motivate students to undertake thorough library research and beneficially use the expert consultation.

Assessment — science, etc.

- Aseptic techniques, use of plates;
- library/expert information gathering;
- accurate mass and volume measurements, use of indicators, flame tests;
- instrument choice and use; component choice, circuit assembly, record taking;
- use of graphical displays (software); log and inverse functions;
- proportion and standard deviation (software);
- library research, note taking, interviewing.

During the course of the assignment, group dynamics will be observed as well as good laboratory practice and safe working. Students will be encouraged to take notes in a log book.

Example of mark scheme (biology)

- Organisation and planning of procedure. Assembling apparatus required, including agar at the correct rate of cooling.

/10

- Carrying out serial dilutions with aseptic techniques, before, during and after the transfer operations.

/10

- Agar pouring and mixing.

/10

- Calculation.

/5

AIMS

- To establish the meaning of superconductivity and its role in society now and in the future, by document research;
- to produce a superconducting substance and explore its properties, by practical work (or demonstration).

STATEMENT OF REQUIREMENT

- Via common skills:
  - — review the main area of application of superconductivity from articles in journals and the press;
  - — review the progress towards room temperature superconductivity;
  - — comment on how industry influences much scientific research and makes science a servant of society;
  - — consider the effects upon society of room temperature superconductivity.
- Via chemistry:
  Draw together the evidence and try to discover the thought processes which told scientists where to look for higher temperature superconductors. Use the following pointers:
  - — high density states;
  - — copper — 3d levels;
  - — strong-bonded linear chain molecules;
  - — disproportionation reactions;
  - — ceramics — Perovskite structures.
- Via physics:
  - — Determine in what ways superconductivity differs from normal metallic conductivity.
  - — Is superconductivity the best name? Consider perfect diamagnetism and comment.

From your work, make a list of specific objectives to be achieved.

PLANNING

(This will depend to a large extent on whether the practical work is student-centred or teacher-demonstrated.)

Plan your strategy for achieving results from the documentation research given in the statement of requirements. Designate areas of responsibility within the team.

Discuss with a member of staff the planning of the practical work.

IMPLEMENTATION

Practical work:

- safety (toxic substances, furnace, etc.);
- pestle and mortar;
- use of furnace;
- use of thermocouple for temperature measurement;
- pill-forming and annealing;

- **demonstration of superconductivity.**

EVALUATION

Check what has been achieved against the statement of requirement given and your own list of objectives.

PRESENTATION

Make a group presentation and cover:

- the meaning/definition of superconductivity;
- science as the servant of society;
- the effect of room-temperature superconductivity on society.

FURTHER INFORMATION

Superconductivity kits suitable for use in this assignment may be obtained from:

Goodfellow
The Science Park
Cambridge CB4 4DJ

As a first step towards making recommendations with regard to staff development in preparation for the introduction of the key technology concepts, a one-day staff seminar was held at GlosCAT to which staff from all parts of the college were invited. Perhaps inevitably, most of the delegates were from technological areas — engineering, science, electronics, computing — which points to a need to emphasise the broader applications of the concepts.

The aims of the seminar were to:

- explain the concepts of key technologies and their implications for the teaching/learning process;
- explore the skills which would be demanded of the teacher in adopting a key technologies approach;
- identify the consequent staff-development and other needs of the teacher;
- investigate strategies to meet these needs;
- experience the first stages in the development of an integrative assignment, based on a key technologies theme.

In planning the seminar, the importance of selecting strategies and deploying activities which would themselves be appropriate to the spirit of the key technologies concept, i.e. which would be active, participative and experiential, were paramount.

The format for the day was:

- an introduction to the concept of key technologies by the project director;
- a presentation, by four members of the research team, of their work to date;
- a discussion of the staff-development implications (see Chapter VI);
- a brainstorming session in which groups would consider the skills required of the teacher, their needs, including staff development needs, and strategies for meeting these;
- a group exercise, focusing on the first stages in developing an integrative assignment;
- a plenary presentation of the outcome of the above group exercise.

At the end of the seminar, participants were asked to complete a personal action plan (PAP). This stressed that the seminar could itself only address a limited number of issues, but that it might have raised others which participants might like to explore further. The PAP provided an opportunity to record and share these intentions.

The seminar was evaluated as part of the evaluation of Grant Related In-Service Training (GRIST) activities within the local authority, and used as a case study in a staff development video promoted by the DES.

GROUP ACTIVITY

For this exercise you are to work in small groups, based on major groupings of subject area.

Choose a member of the group, X, who has the least familiarity with devising and using cross-curricular assignments.

The other members of the group are to act as consultants/ advisers/sounding boards, to assist in devising an assignment based on some aspect of emerging technology from within X's area of interest.

The task, then, is to

- decide on a key technology theme which could form the basis of an assignment;
- set a scenario around this theme; this needs to be realistic and relevant, and require students to work in groups, plan their own work, make decisions, manage time, communicate, etc. (An example might be 'The food firm for which you work is aiming to expand into the synthetic protein market. Your project team is asked to produce a report to the Managing Director on the various types of synthetic protein and their acceptability to the public.');
- list the aims and/or objectives (technological and core) you intend the students to achieve through the assignment;
- develop the assignment, dividing it, where appropriate, into smaller constituent tasks;
- write students' instructions for the assignment in user-friendly terms;
- consider how you will assess the assignment (including group/individual components).

Remember, you all have different experiences in devising and using assignments as vehicles for learning and assessment — use this experience.

If today has been successful it will have raised many issues. It may have answered a few, but there should be many others which you would like to explore further.

This is an opportunity to record these and to share with someone your intentions and expectations. (It will also embarrass you into doing something about them!)

The message I intend to take back to my course team(s) is:

— — — — — — — — — — — — — — — — — — — —
— — — — — — — — — — — — — — — — — — — —
— — — — — — — — — — — — — — — — — — — —
— — — — — — — — — — — — — — — — — — — —

Working with my course team(s), these are the changes I would like to make to:

- the curriculum: — — — — — — — — — — — — — — — —
— — — — — — — — — — — — — — — — — — — —
— — — — — — — — — — — — — — — — — — — —
— — — — — — — — — — — — — — — — — — — —

- how it is delivered: — — — — — — — — — — — — — — —
— — — — — — — — — — — — — — — — — — — —
— — — — — — — — — — — — — — — — — — — —
— — — — — — — — — — — — — — — — — — — —

These are some of the examples of key technologies from my teaching area which I would like to find out more about:
— — — — — — — — — — — — — — — — — — — —
— — — — — — — — — — — — — — — — — — — —
— — — — — — — — — — — — — — — — — — — —
— — — — — — — — — — — — — — — — — — — —

People who can give me further ideas are — — — — — —
— — — — — — — — — — — — — — — — — — — —
— — — — — — — — — — — — — — — — — — — —
— — — — — — — — — — — — — — — — — — — —

The personal skills I need to work at are — — — — — —
— — — — — — — — — — — — — — — — — — — —
— — — — — — — — — — — — — — — — — — — —
— — — — — — — — — — — — — — — — — — — —

The following staff development activities will help me develop these skills: — — — — — — — — — — — — — —
— — — — — — — — — — — — — — — — — — — —
— — — — — — — — — — — — — — — — — — — —
— — — — — — — — — — — — — — — — — — — —

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'A' level	General Certificate of Education, Advanced level
ACS	Average class size
ALH	Average lecture hours per week
'AS' level	General Certificate of Education, Advanced Supplementary level
ASH	Average student hours per week
BTEC	Business and Technician Education Council
C&G	City and Guilds of London Institute
CDP	Committee of Directors of Polytechnics
CDT	Craft, Design and Technology
CIHE	Council for Industry and Higher Education
CNAA	Council for National Academic Awards
CPVE	Certificate of Pre-Vocational Education
CSE	Certificate of Secondary Education
DES	Department of Education and Science
FE	Further education
FEU	Further Education Unit
GCE	General Certificate of Education
GCSE	General Certificate of Secondary Education
GlosCAT	Gloucestershire College of Arts and Technology
HE	Higher education
HMI	Her Majesty's Inspector (Inspectorate)
INSET	In-Service Education of Teachers
LEA	Local education authority
NCVQ	National Council for Vocational Qualification
NVQ	National Vocational Qualifications
SSCR	Secondary Science Curriculum Review
SSR	Staff:student ratio
TES	*Times Educational Supplement*
TGAT	Task Group on Assessment and Testing
THES	*Times Higher Educational Supplement*
TVEI	Technical and Vocational Education Initiative

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The objects for which the **Further Education Unit (FEU)** is established are to promote, encourage and develop the efficient provision of further education in the United Kingdom and for that purpose:

a) to review and evaluate the range of existing further education curricula and programmes and to identify overlap, duplication, deficiencies and inconsistencies therein;
b) to determine priorities for action to improve the provision of further education and to make recommendations as to how such improvement can be effected;
c) to carry out studies in further education and to support investigations of and experimentation in, and the development of, further education curricula and to contribute to and assist in the evaluation of initiatives in further education;
d) to disseminate and publish information, and to assist in the dissemination and publication of information, about recommendations for and experiments and developments in further education.

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